Microturbines

US DoE DER Roadshows
April, 2003

What Is A Microturbine?

- Microturbines: a new way to locally supply continuous energy to facility
- Installed inside or near a building to provide electricity and optionally, heat
- Similar to a placing a furnace, boiler, backup genset, or chiller in a facility

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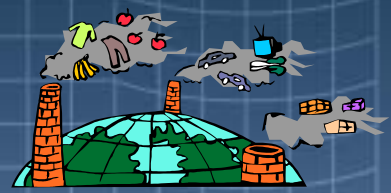
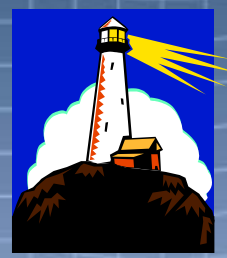
How Does It Help The Customer?

An opportunity to:

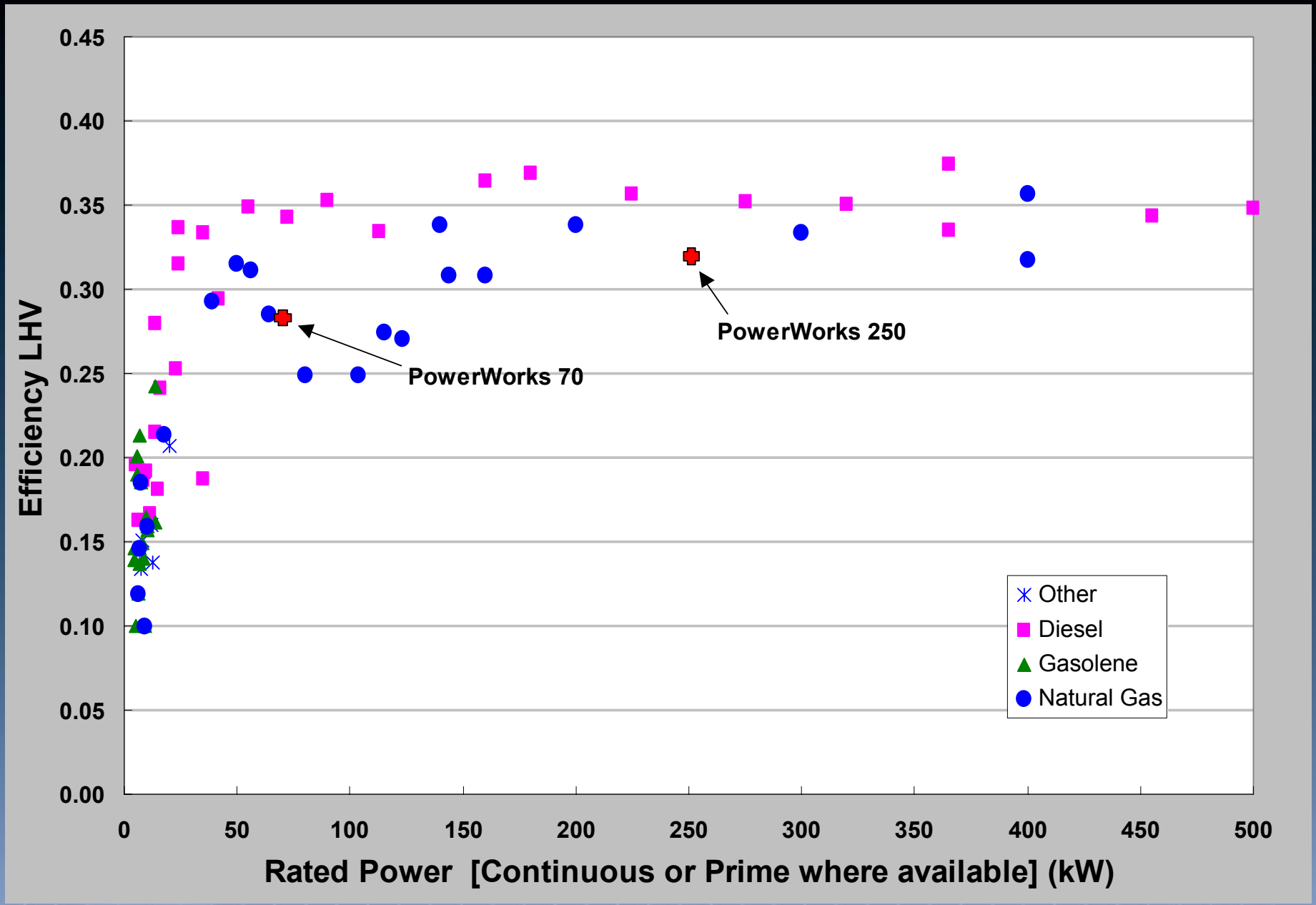
- Save money buying energy
  - Avoid penalty tariffs
  - Isolate loads to minimize demand charges
- Support energy conservation efforts
- Reduce environmental impact
  - Stop flare emissions
  - Safely destroy VOCs
- Avoid power outages
  - Eliminate production losses
  - Provide power during emergencies
  - Isolate priority loads in problem power areas
- Potentially helps solve facility power problems
  - Produce power where needed
  - Help correct power factor problems
  - Provide power to remote sites





Microturbine Advantages

- Clean electricity
- Very low emissions
- Quiet operation
- Low maintenance
- Long engine life
- High system efficiency
- Multi-fuel operation
- Cogeneration heat


0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Efficiency LHV
0
50
100
150
200
250
300
350
400
450
500
Rated Power [Continuous or Prime where available] (kW)
PowerWorks 70
PowerWorks 250
Other
Diesel
Gasolene
Natural Gas

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Applications

Customer Motivations	Cost Savings	Power Availability	Power Generation	Power Quality	Environ. Compliance
Typical Application Segments	Agriculture, Hotel, Chemical	Health Care, Universities, Food Distrib.	Landfill, Mining, Wastewater	Communication, IT, Hi-Value Mfg	Petroleum, Process, Materials

Type of Service					
Cogeneration	✓	✓	✓		✓
Peak Shaving	✓	✓	✓		✓
Prime Power			✓	✓	✓
Running Backup	✓	✓		✓	
Remote Power			✓	✓	

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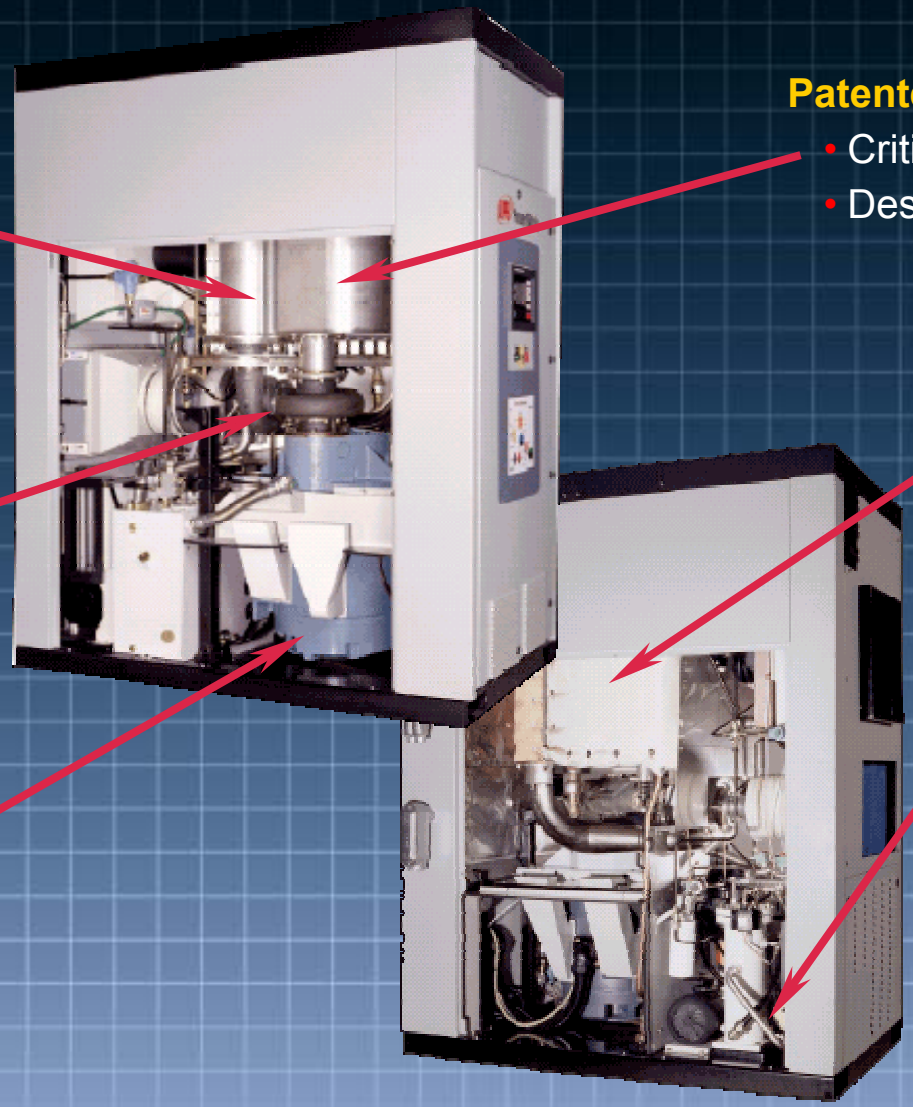
PowerWorks® 70kW Key Features



Patented Combustor

- Dry low NOx
- Easily meets stringent environmental regulations

Two-Shaft Engine

- Reduces stress for longer life

Proven Generator Technology

- Well understood by utilities
- Same technology used by utilities to power the grid

Patented Recuperator

- Critical to high efficiency
- Designed for 80,000 hour life

Integrated Heat Recovery

- Smaller footprint
- Controllable output level

Fuel Gas Booster

- Long-life design
- Fully integrated
- IR technology already used in thousands of critical industrial applications

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PowerWorks 70kW Specifications

- 70kWe model
- Has 130% peaking power capacity on cold days (92 kWe)
- Efficiency
  - Induction system: 29% LHV electric (28% w/booster)
  - Synchronous system: 28% LHV electric (27% w/booster)
  - Up to 70% total with cogeneration
- Low emissions with natural gas
- 8,000 hour maintenance interval
- 80,000 hour engine life
- Grid-parallel or grid-isolated electrical generation
- Closed transitions to grid-isolated mode during grid outages
- Automatic block load handling up to 70kW

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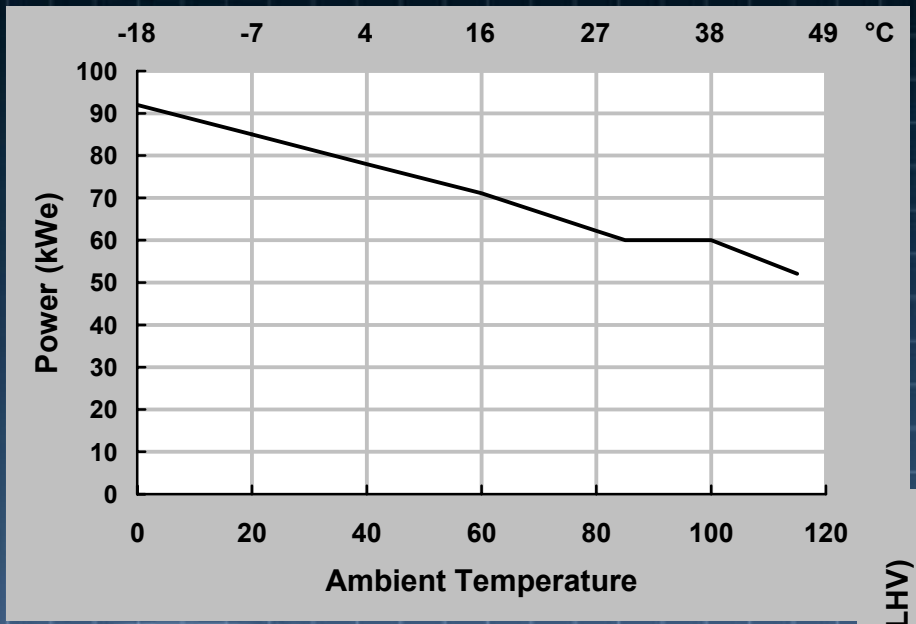
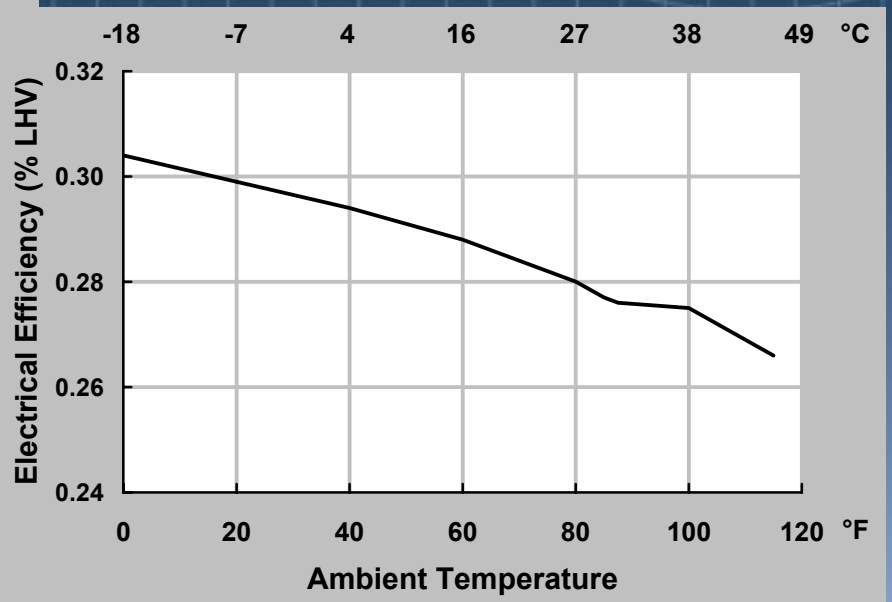
70kW PowerWorks Performance (Induction)



Note: KWe is electrical output at terminals corrected for parasitics, but not including gas booster power.



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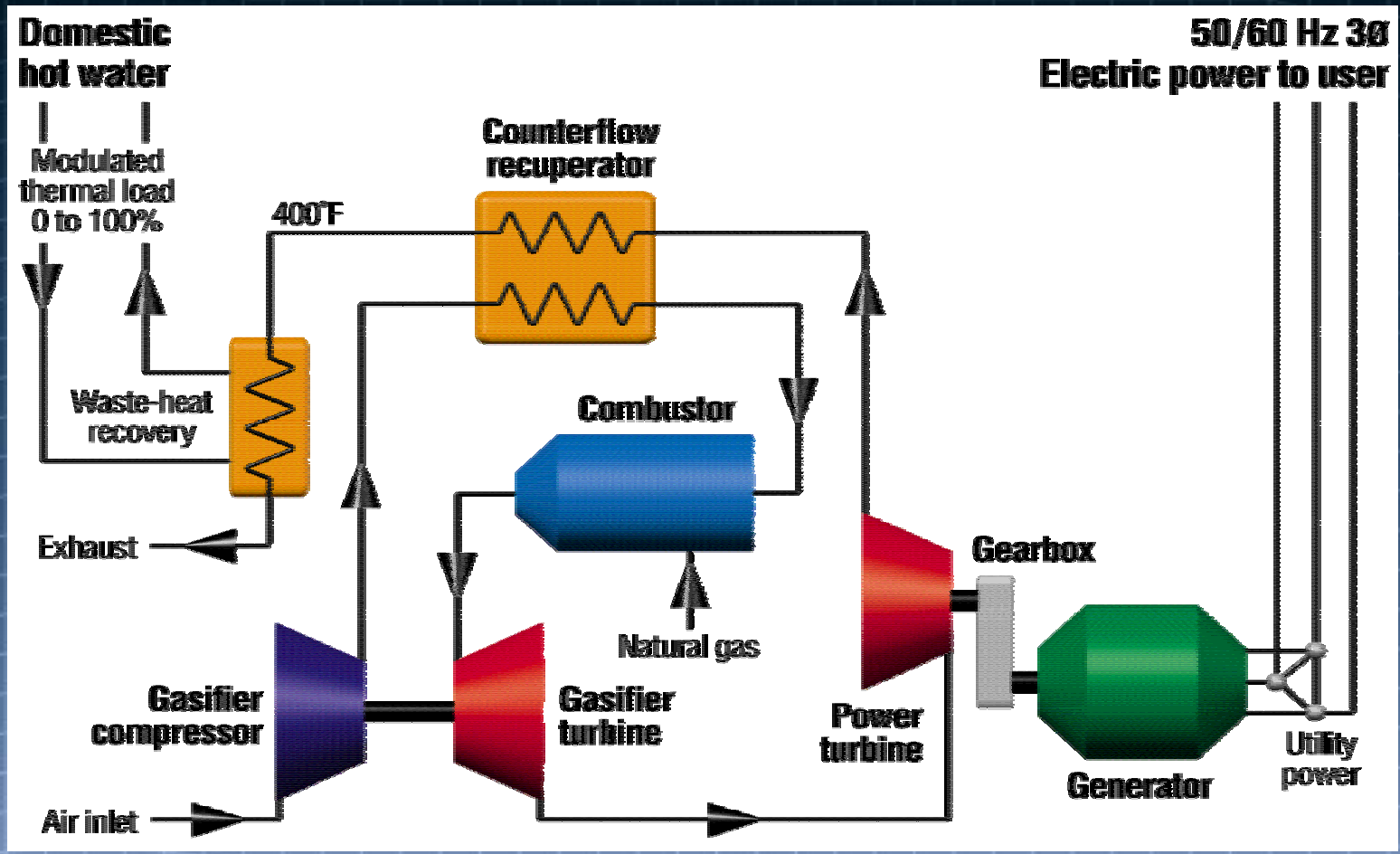
System Cycle Diagram



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250kW PowerWorks Specifications

- 250kWe model at ISO conditions
- Has 120% peaking power capacity on cold days (300 kWe specified)?
- Efficiency
  - 32% LHV electric w/booster
  - Up to 70% total with cogeneration
- Low emissions with natural gas
  - <9 ppmv NOx @ 15% excess O_2
- 8,000 hour maintenance interval
- 80,000 hour engine life
- 3x footprint of 70kW
- Grid-parallel or grid-isolated electrical generation (synchronous gen.)
- Closed transitions to grid-isolated mode during grid outages
- Engine principally handles block load changes alone

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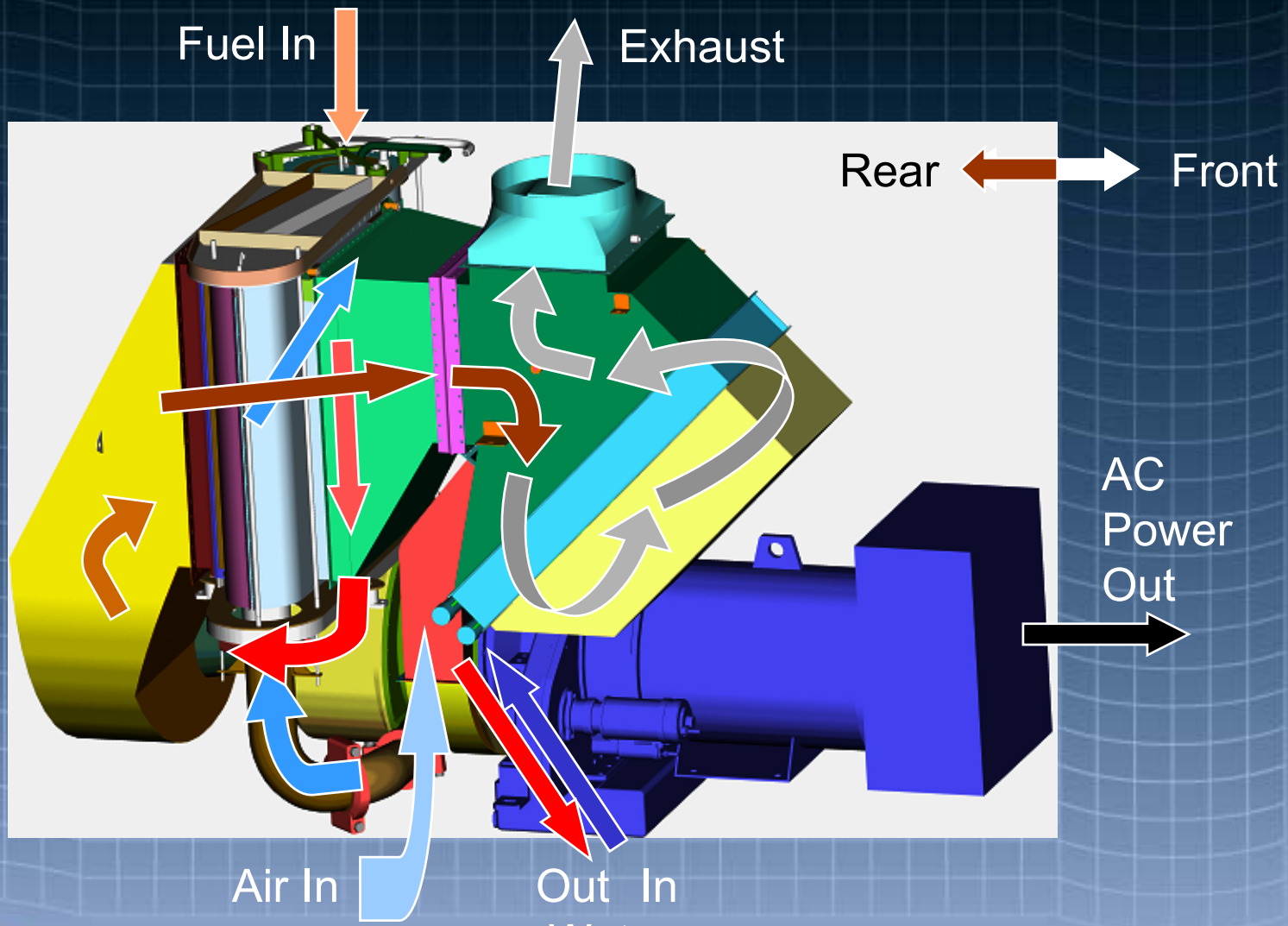
Prime Mover Configuration



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Davidson, NC Final Assembly

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IR's US Service Coverage

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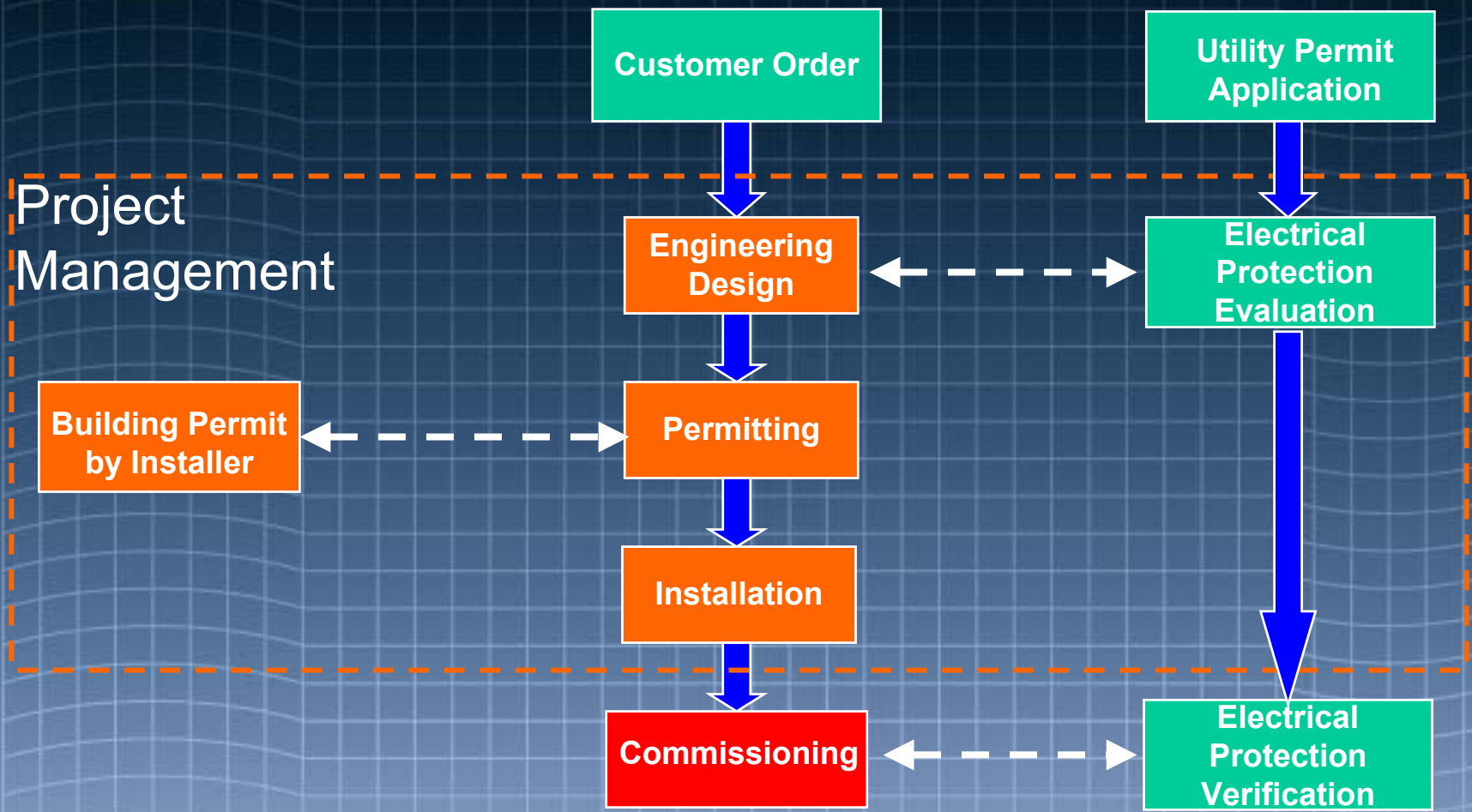
Codes Used in Development

• UL 2200	Stationary Engine Generator Assemblies
• NFPA 37	Stationary Combustion Engines
• NFPA 54	National Fuel Gas Code
• NFPA 70	National Electric Code
• EGSA	Safety Codes Required by States & Major Cities
• ANSI / NSF 51	Standard for Food Equipment
• ANSI C84.1 (60Hz)	Electric Power Systems & Equipment Voltage Ratings
• ANSI 133.8	Gas Turbine Installation Sound Emissions
• ANSI 133.9	Measurement of Exhaust Emissions From Stationary Gas Turbine Engines
• ANSI B133.10	Gas Turbine Information to be Supplied by User and Manufacturer
• EPA Section 1417	Safe Drinking and Water Act
• CSA C22.2 #100	Motors and Generators, Industrial Products
• OSHA 1910.95	Occupational Noise Exposure
.101	Compressed Gases
.144	Safety Color Codes for Physical Hazards
.145	Signs and Tags
.146	Permit Required Confined Spaces
.147	Control of Hazardous Energy

Other Codes That Can Apply

- UL1741 - Converters / Inverters / Charge Controllers For Independent Power Systems
- Existing Electrical Interconnect Standards
  - NY: PSC Standardized Interconnect Requirements …
  - CA: Rule 21
- Future:
  - IEEE SCC21 P1547 National Interconnect
  - FERC Small Generator Interconnect
  - MA: Collaborative Interconnection Standard
- Major building codes :
  - National Building Code
  - Uniform Building Code
  - Standard Building Code
- Geographic-specific codes:
  - New York State Uniform Fire Prevention and Building Code Title 9B NYCRR
- US EPA, State, and Local Emissions Requirements

The Installation Process



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Compact Footprint Enclosure

- Qualified for indoor use
- Low noise level: 78Dba @ 1 meter
- Built-in industrial controls
- Special foundation not required
- Independent inlet air ducting
  - 1100 to 1500 scfm typical
  - Cool, filtered air preferred
  - Consider using building exhaust

69L x 42W x 87H in (175L x 107W x 221H cm)
4100 or 4850 pounds (1860 or 2200 kg)

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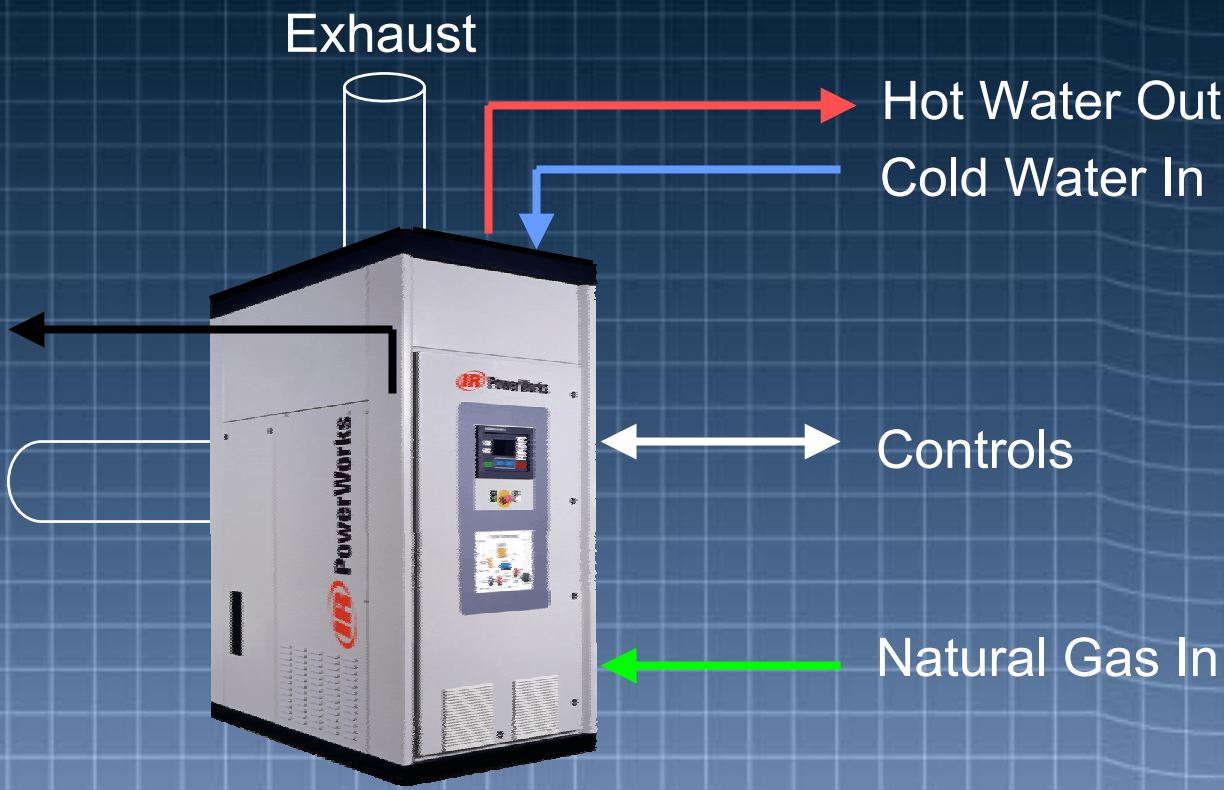
Facility-Microturbine Integration

Physical Layout



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Typical Indoor Installation

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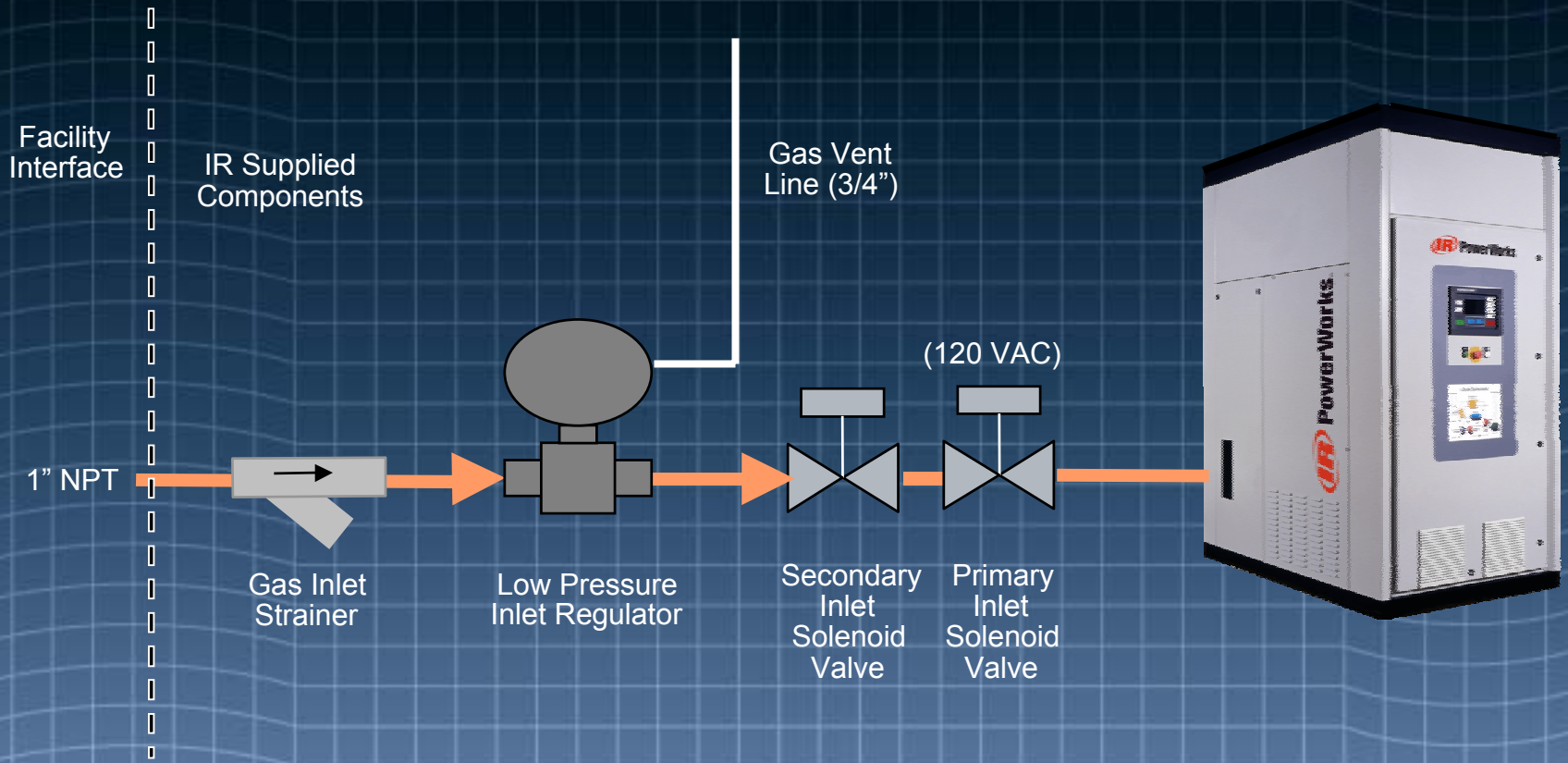
Natural Gas Input



- **Sealed fuel handling system**
- **Minimum inlet pipe pressure = 0.29 PSIG**
- **Minimum flow = 52.9 lbm/hr**

Prime Mover Fuel Specifications

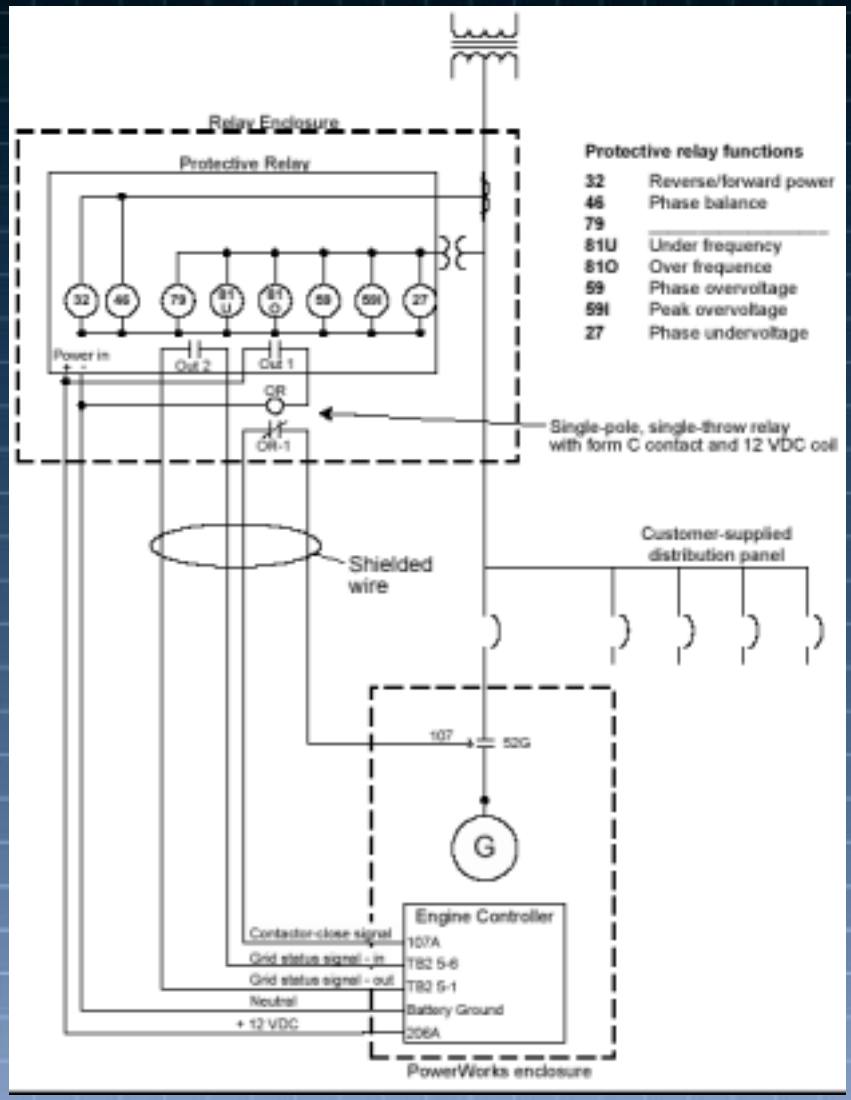
Table 4: Composition of the Gaseous Fuel

Composition	Limit	Comment
Oxygen	3% max	Do not exceed the flammability limits.
Hydrogen	5% max	Concern is that this increases flame speed which could lead to durability reduction of the fuel injection apparatus of the combustor
Fuel Bound Nitrogen	2 ppmv	Forms fuel bound NOx
Carbon Dioxide	45% max	Limit corrosive potential of gas in presence of moisture
Methane	38% min	Equals minimum required fuel energy content
Ethane	8% max	
Propane + Butane	2% max	
Moisture	150 ppmv max	Corrosion concerns

Table 5: Contaminate Limits of Gaseous Fuels

Contaminate	Limit	Comment
Hydrogen Sulfide (H2S)	25 ppmv max	Brief periods to 200 ppmv allowed
Siloxanes	5 ppm max	Concern of corrosion and fouling
Particulate	3 microns avg. size	Prevent rapid plugging of fuel filter
Halogenated Organic Compounds	200 ppmv max	
Non-methyl Organic Compounds	1500 ppmv max	
Alkali metal sulfates (Na, K, Li)	0.6 ppm mass max	Hot section corrosion

Simple Intertie Electrical Interconnect



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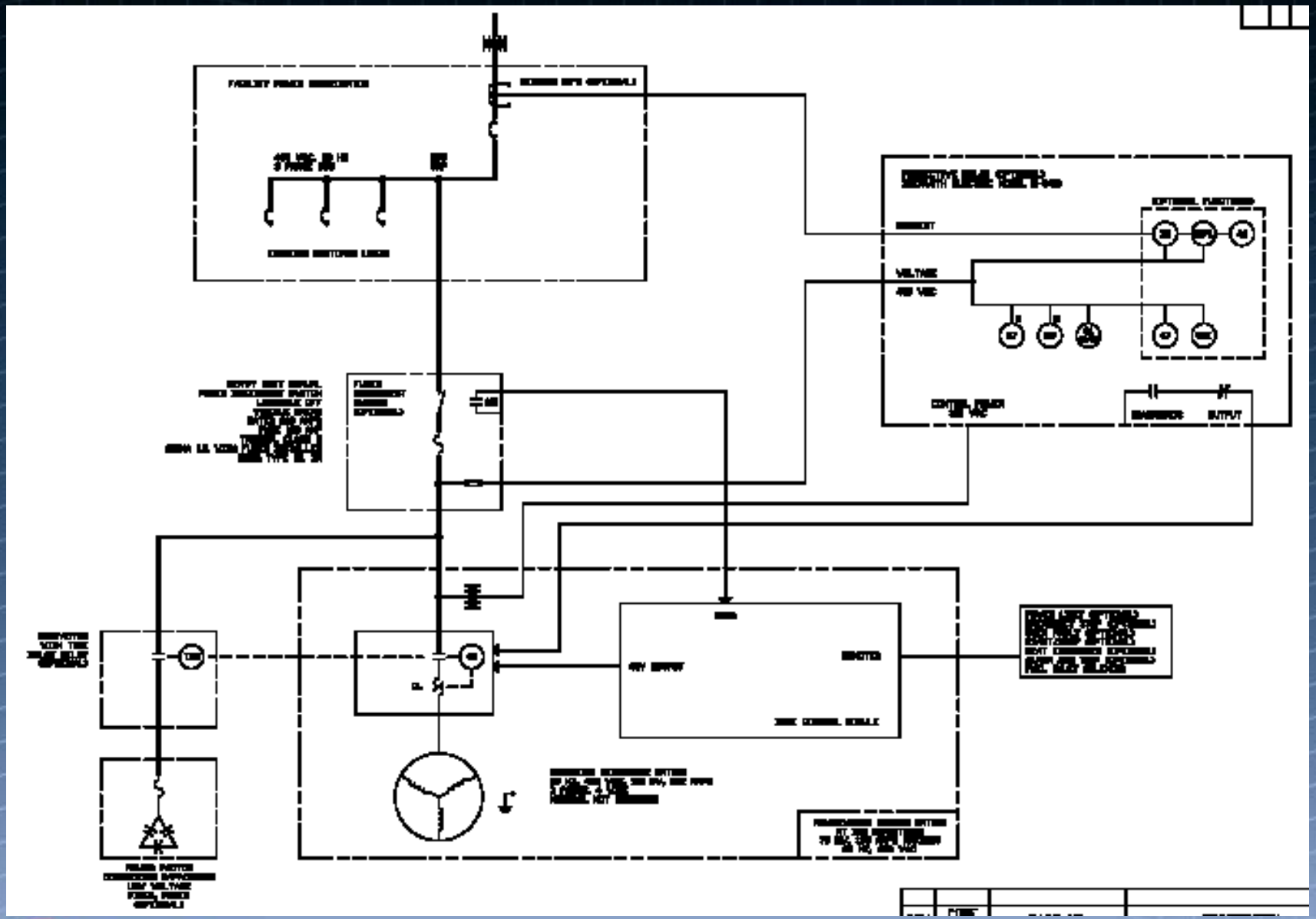
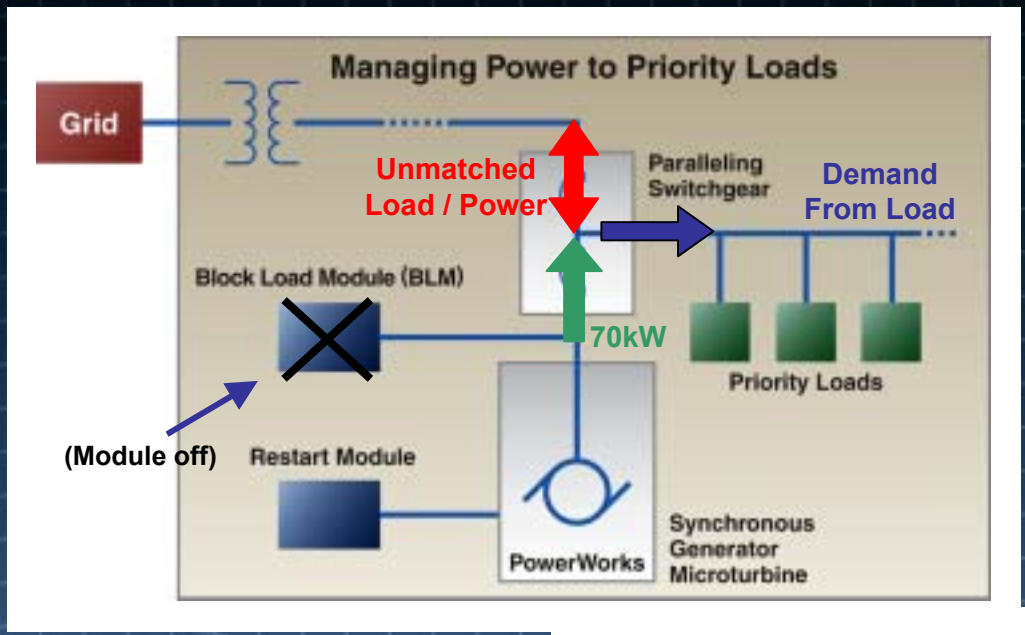
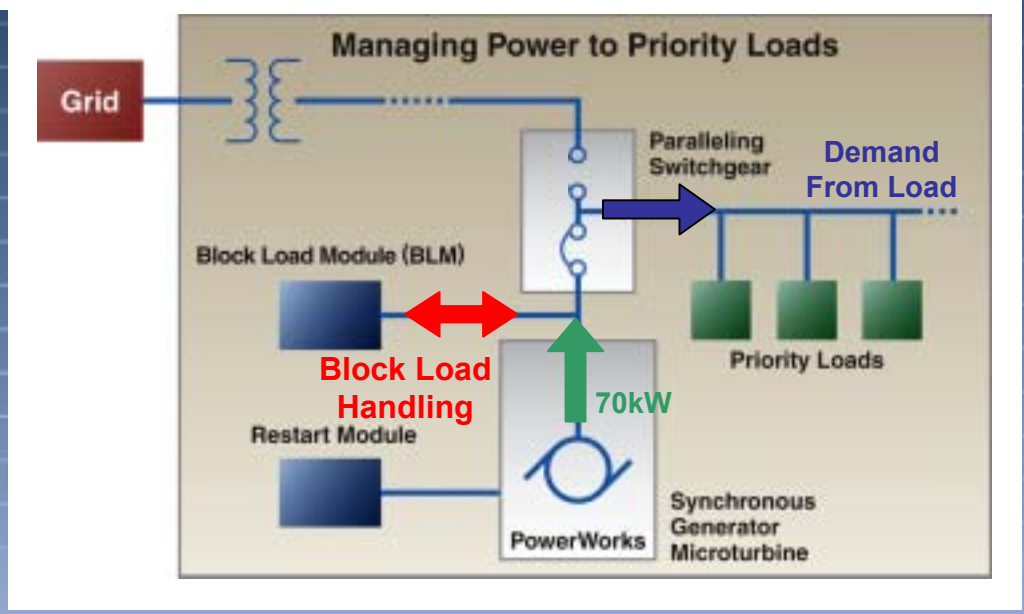
Typical Induction System One-Line



Synchronous System Capability





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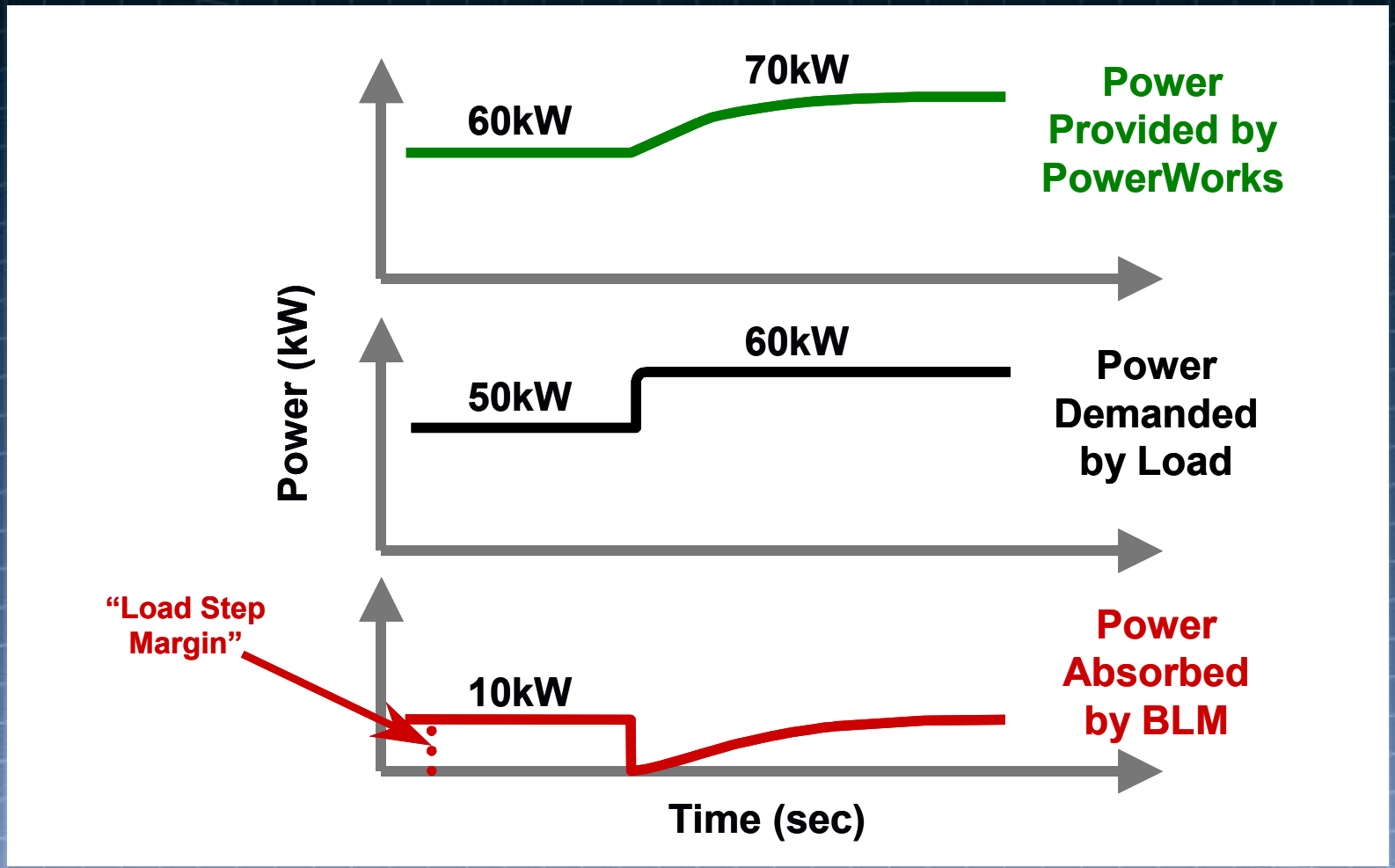
Block Load Margin Control



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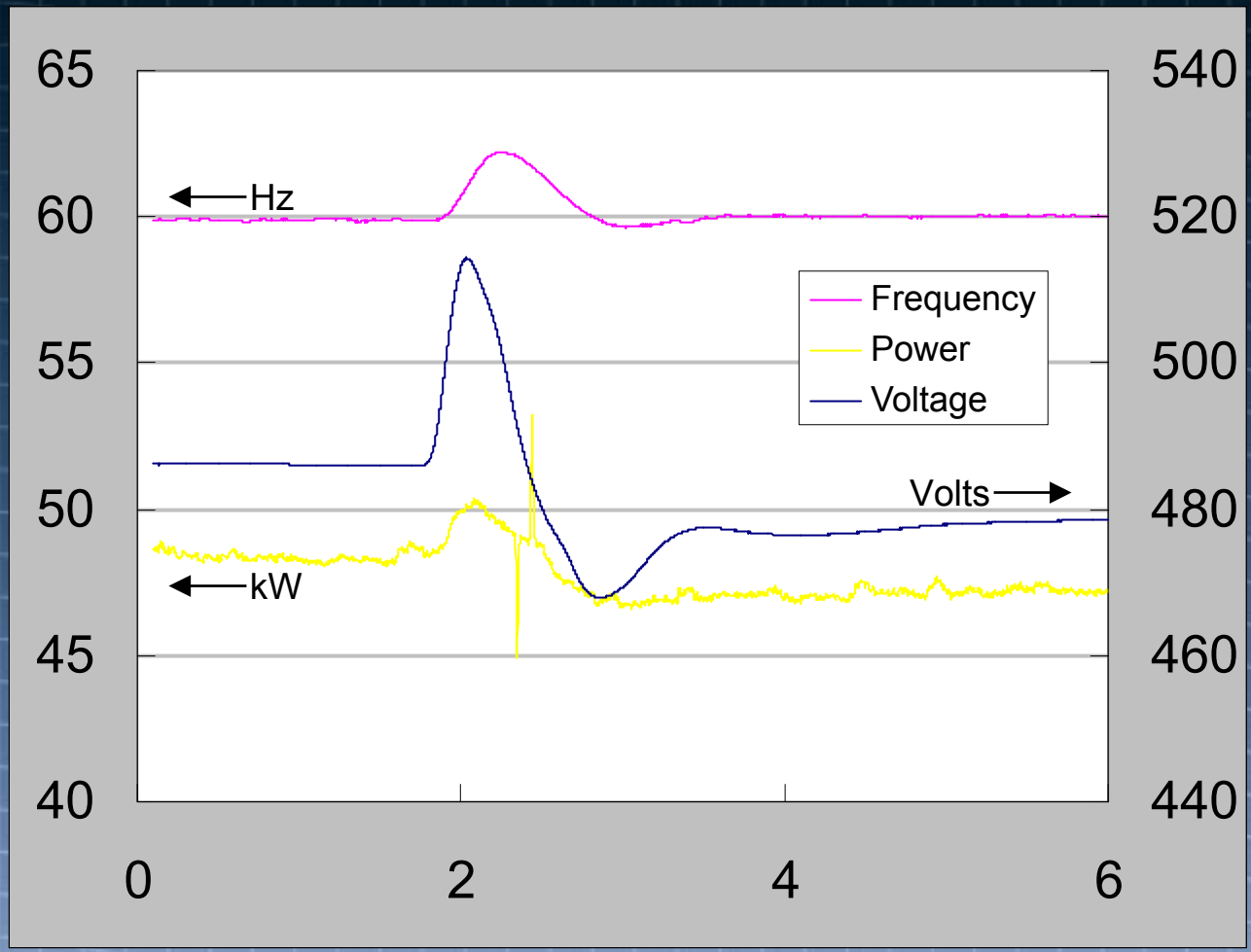
Grid-Parallel To Grid-Isolated Detail



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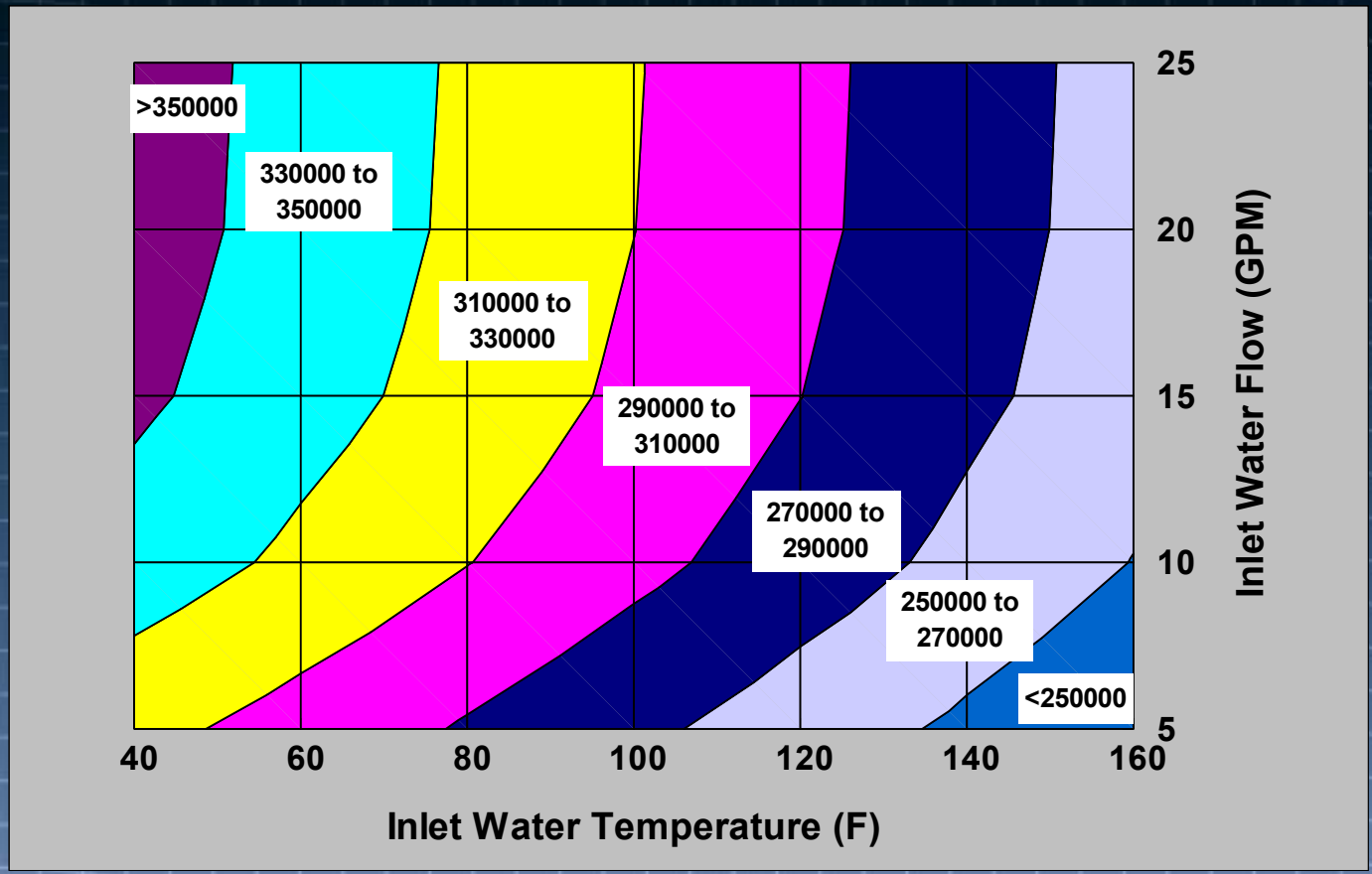
Fully Integrated Heat Recovery System

- Built into exhaust plenum immediately after recuperator
- Designed for heating water
  - 6 to 26 gpm
  - Up to 200°F water output
  - Suitable for potable water up to 125 psig
  - Example: 278,000 BTU/hr @ 20GPM with inlet water temperature of 140ºF
- Heat can also be recovered directly from exhaust
  - About 421°F after recuperator
  - Very clean, perhaps cleaner than input air!

Heat Recovery Output BTU/hr



- Recovered BTU/hr depends on inlet temperature and flow rate

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70kW Air / Exhaust Handling

- Independent inlet air ducting
  - 1100 scfm typical
  - Cool, filtered air preferred
  - Max duct pressure loss = 0.25” H2O
- Exhaust
  - Dry, low-NOx technology
  - NOx: <9 ppmv @15% O2
    <0.045 lbm/hr (<20 gm/hr)
  - CO: <9 ppmv @15% O2
    <0.045 lbm/hr (<20 gm/hr)
  - Max duct pressure loss = 0.75” H2O

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Low Emissions Combustion

- 70kW Specification at ISO Conditions:
  - NOx <0.41 lb/MWh (<9 ppmv @ 15% excess O2)
  - CO <0.25 lb/MWh (<9 ppmv @ 15% excess O2)
- 2003 California Air Resource Board Limits:
  - NOx <0.5 lb/MWh
  - CO <6.0 lb/MWh
  - VOC <1.0 lb/MWh
- Preliminary certification testing of 70LM:
  - NOx <0.15 lb/MWh
  - CO <0.25 lb/MWh
  - VOC <0.05 lb/MWh
- Testing by outside agencies confirms low levels

Hard-Wired Control Inputs and Outputs

- Remote Emergency Stop
- Remote Stop/Start
- Facility Fault Input
- Heat recovery On/Off
- Upstream Breaker Contact Position
- PowerWorks Alarm Indicator
- Fuel Inlet Solenoid Valve
- Protective Relay Contact

Remote Serial Monitoring / Control

Analog Values

- Remote kW Setpoint
- Electric power
- Fuel orifice differential pressure
- Fuel orifice temperature
- Fuel inlet temperature
- Water inlet temperature
- Water inlet temperature setpoint
- Water outlet temperature
- Gas generator compressor inlet temperature
- Turbine outlet temperature
- Compressor inlet temperature
- Intake air filter differential pressure
- Gas generator spindle rpm
- Electric generator rpm
- Running hours
- Number of starts
- Power-on hours

Digital Values

- Engine state flags
- Generator state flags
- Generating electricity
- First out alarm
- First out trip

Digital Commands

- Remote start
- Remote stop

Typical Power Needs For Facilities

• Convenience Stores	40 to 50 kW
• Fast Food	40 to 50 kW
• Restaurant Chain	50 to 70 kW
• Filling Stations	50 to 70 kW
• Box Stores	200 to 400 kW
• Older Supermarkets	150 to 300 kW
• Landfills	500kW (gas equiv)
• New Supermarkets	300 to 2,000 kW
• Hospitals	100 to 6,000 kW
• Hotels	200 to 2,500 kW
• Large Office Buildings	400 to 3,000 kW
• Universities	1,000 to 4,000 kW
• Factories	500 kW and up
• Waste Treatment	1.5 to 10MW

Applications - Community Center

- Skilled nursing facility located in NY
- 60,000 sqft facility
- PowerWorks generates hot water that provides most of the facility's Domestic Hot Water (DHW) needs
- Installed in new outside building
- Natural gas fuel
- 24/7 electricity (base load)

IR PowerWorks.

Applications - Landfill

- Replaces Honeywell microturbines
- Installed in newly roofed area
- Low BTU fuel from degradation of biological waste (350 BTU / ft3 minimum?)
- 24/7 electricity (base load) exported to grid
- No heat recovery components (cogeneration)

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Applications - Greenhouse

- Claims highest yield of roses per sq-m in the world
- Winter: electricity defers sun lamps load
- Summer: electricity defers heat pumps load
- Recovered heat used to warm plant beds

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Applications - Industrial

- LCN - Division of IR Security & Safety in Illinois
- Offers heavy-duty fire/life/safety door closers
- Reservoir pumps city water to the microturbines which heat the water for use in a five-stage parts washing process
- Natural gas fuel input

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Applications - Landfill

- OII (Operating Industries), Monterey Park, CA
- Inactive super-fund toxic waste landfill site
- Constant flaring at ~24% methane content
- Six PowerWorks units operating at 38-40%
- Exhaust gases are flared to ensure complete burning of gas
- Perimeter wells prevents landfill gases from affecting surrounding family dwellings

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